Episodic Upwelling of Zooplankton within a Bowhead Whale Feeding Area near Barrow, AK

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LONG-TERM GOALS

Our long term goals are to understand (1) the biological-physical oceanographic characteristics and mechanisms on the shelf near Barrow, AK that together produce a favorable feeding environment for the bowhead whale there and (2) the potential impact of climate change, particularly the ongoing reduction in sea ice and variability in Pacific Water presence near Barrow, on this feeding environment. This region is a critical feeding area for migrating bowhead whales, particularly during the fall migration (e.g., Lowry et al., 2004). Results from biophysical sampling conducted during August-September 2005- 2008 demonstrated that the oceanography of the shelf is complex, dynamic, and highly variable and that advection is closely coupled to the direction and magnitude of the winds. In addition, oceanographic and atmospheric conditions impact the composition, distribution, and availability of plankton prey for the bowhead whale. Assessment and understanding of interannual and longer-term variability in the physical mechanisms influencing ocean conditions and the resulting

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distribution and abundance of plankton on the shelf are necessary to predict potential impacts of climate change.

OBJECTIVES

Our overall objectives are to explicitly identify and document the occurrence, frequency, and persistence of wind-driven shelf-slope exchange events at the Barrow Canyon and the Beaufort shelf breaks during the summer and early fall in association with the presence of ice cover, water column stratification, and the presence of bowhead whales and to further document short-term and interannual variability in the ocean system and how this variability is associated with changes in climate and ice.

1. Document exchanges of Pacific Water and plankton/krill (acoustic backscatter as a zooplankton proxy) between Barrow Canyon and the adjacent Beaufort shelf over two full years.
2. Document shelf-slope exchanges between the Beaufort Sea and Beaufort shelf.
3. Determine the seasonal occurrence of bowhead whales in the study area via year-round sampling for marine mammal vocalizations using autonomous recorders.
4. Determine the correlations between exchange events and wind speed and direction, wind duration, ice cover, shelf water column stratification, whale presence or absence, and whale prey selection.
5. Conduct surveys along transects running across Barrow Canyon and across the shelf to ground-truth mooring observations and to continue the two-year time series of observations collected during the larger, NSF funded project to further describe interannual variability and hydrographic and associated biological characteristics on the shelf during early September and to provide critical information for validation of oceanographic modeling of the region.

APPROACH

This project is a partnership between the academic PIs listed above (Ashjian, Campbell, Okkonen, and Stafford), collaborators at Oregon State University (B. Sherr and E. Sherr), a collaborator at NOAA (S. Moore), and a collaborator at the North Slope Borough Department of Wildlife Management (C. George).

The objectives are being addressed through three main field approaches: Boat Based Oceanographic Sampling (Task 1), Year-Long Oceanographic Moorings (Task 2), and Bowhead Whale Prey Analysis (Task 3). Data analysis and presentation of results (Task 4) and Outreach (Task 5) are accomplished simultaneously with the three work approaches.

WORK COMPLETED

Boat-based oceanographic sampling was not conducted this year under this NOPP grant. However, this sampling was continued through funding from NOAA/BOEMRE and the NSF Arctic Observing Network (AON) program. The additional sampling will permit us to continue to understand oceanographic variability near Barrow, AK. The NOPP sponsored sampling of 2008 and 2009 is an integral part of that understanding. Preliminary analysis of interannual variability in biological and

physical ocean conditions for 2005-2009 (inclusive of years funded by this project) were presented orally at the 2010 Ocean Sciences Meeting in Portland OR (Ashjian et al., 2010).

Two year-long oceanographic moorings deployed in late July 2009 were recovered 12 September 2010 by the *USCGC Healy* (see Figure 1 for mooring locations). Both moorings were instrumented, bottom to top, with an acoustics recorder to archive marine mammal vocalizations, microcat CT sensor to measure water temperature and salinity, and Onset/HOBO ProV2 temperature sensors at 25-m, 40-m, 50-m, 60-m, 65-m, 70-m, and 75-m above the bottom (Figure 2). The eastern mooring was also instrumented with upward-looking Teledyne/RDI 300 kHz ADCP at 7-m above the bottom to aid in monitoring the movement of zooplankton between the slope and shelf and to describe current sppeds and directions, particularly those associated with shelf-break upwelling events. Upon recovery, it was found that the uppermost floatation buoy and HOBO on each mooring string was torn away and the remaining four HOBO temperature sensors on the breakaway line were inverted and hanging below the floatation buoy placed at 45-m above the bottom. The whale acoustics recorders, microcats, and ADCP were recovered and oceanographic data from these instruments presently are being analyzed. The microcats and HOBO sensors recorded data for the full 13.5-month mooring deployment period. Both whale recorders recorded for a full year (August 2009-August 2010). The ADCP recorded 12.5 months of data; data was not acquired during the last month of the deployment period due to loss of battery power in mid-August 2010. It should be noted that the recovery of these moorings was originally scheduled for late July-early August 2010, but a schedule change for the *Healy* pushed the recovery back until mid-September.

Bowhead whale prey analysis was conducted by C. George on whale stomach contents collected by C. George and local whalers during the IWC sanctioned fall whaling seasons of 2008-2010.

RESULTS

Ocean temperatures measured during the boat based oceanographic sampling in August-September 2010 were similar to those observed during 2005 (Figure 3), with warmest ocean temperatures at ~8°C. Significant year-to-year variability in the temperature-salinity characteristics of the waters sampled within the Barrow Canyon-western Beaufort shelf study area has been observed over the six years (2005-2010) (Fig. 5). The 2005, 2007, 2009, and 2010 surveys encountered very warm Pacific Water (>>4 °C), whereas the 2006 and 2008 surveys encountered much cooler Pacific Water. The presence of extensive sea ice cover in 2006 is reflected in the prevalence of sea ice meltwater; meltwater also was observed in 2008 but not significantly in the other four years.

Figure 4 compares time series of temperature and salinity from the 2008/2009 and 2009/2010 deployments at the eastern mooring location. Data from the western mooring are similar to the eastern mooring data and are not shown here. It is apparent that near bottom temperatures recorded during late summer (August-September) were coolest in 2008 and warmest in 2010. The near bottom (94-m depth) temperature reaches 7°C in early September 2010. Temperatures (T > 0°C) and salinities (S > 34) characteristic of Atlantic Water appear less frequently during the 2008/2009 autumn-winter than during the 2009/2010 autumn-winter suggesting that wind-driven upwelling events were more common during the latter period.

Comparative time series of relative acoustic backscatter within the water column at the eastern mooring location are shown in Figure 5. Due to a faulty battery pack cable, acquisition of backscatter data for the 2008/2009 deployment period ceased in early December 2008. The strongest acoustic

backscatter was generally recorded in late summer and early autumn with backscatter relatively weaker during August-October 2008 than during August-October 2009 suggesting that there were more zooplankton present in the western Beaufort Sea during the 2009 autumn Bowhead whale migration than during the 2008 autumn migration. The weakest acoustic backscatter (presumed to indicate comparatively few zooplankton) occurs during spring.

The whale recorders were offloaded from the USCGC Healy on 14 October 2010 and the data downloaded on 15 October 2010 so no preliminary analysis of the 2009-2010 data is available at present. Analysis of the 2008-2009 data is ongoing. In addition to marine mammal calls, the acoustic recorders were very effective recorders of airguns used in seismic surveys in support of oil and gas exploration. Airguns sounds are very loud and discrete and differ markedly from marine mammal vocalizations (Figures 6 & 7).

IMPACT/APPLICATIONS

Our work will provide a greater understanding of the physical and biological factors that produce a favorable feeding environment for the bowhead whale on the shelf near Barrow. This will permit educated decisions regarding development of industry, tourism, and commerce in this region by regulators and policy makers. The work also will provide greater insight into the potential impact of climate change on the Arctic ecosystem. In addition, the continued documentation of interannual variability of the ocean conditions is of both local (importance to shelf ecosystem) and broader importance since the region near Barrow is a critical juxtaposition of the Chukchi Sea and Beaufort Seas and is where much of the Pacific Water flowing through the Chukchi Sea from Bering Strait enters the Beaufort Sea, either through Barrow Canyon or from more western locations in the Chukchi Sea. The Pacific Water supplies heat, nutrients, and organic material including plankton (especially the krill that are the preferred prey of the bowhead whale near Barrow) to the Chukchi Sea and ultimately the Arctic Ocean.

RELATED PROJECTS

This ongoing project is a follow on to a previous National Science Foundation funded project examining “Oceanography, Bowhead Whale Distribution, Climate Variability, and Iñupiat Subsistence Whaling”, with PIs including Ashjian, Campbell, George, Moore, Okkonen, Sherr, and Sherr for which fieldwork was conducted in 2005 and 2006. Many of the hypotheses being explored in this project resulted from data collected during the NSF project. The ongoing project also is a companion to a larger, ongoing NOAA/BOEMRE project “Bowhead Whale Feeding in the Western Beaufort Sea” for which the PIs deployed short-term, shallow oceanographic and year-long marine mammal acoustic recording moorings and conducted additional oceanographic fieldwork during the summer of 2008 and 2009. Additional components of this larger project include aerial surveys of marine mammals/bowhead whales, long-term satellite tagging and short-term suction cup tagging of whales to determine migration paths and feeding behavior, and visual observations of whale behavior and locations from small boats. Together these projects provide a greater understanding of the oceanographic conditions off of Barrow as well as providing opportunities to sample over longer time periods in that region in order to better describe the impact of the strength and magnitude of the wind on upwelling along the Beaufort Shelf and the importance of this mechanism to providing prey on the shelf for the bowhead whale. The ongoing project also complements two other NOPP projects “Circulation, Cross-shelf Exchange, Sea Ice, and Marine Mammal Habitats on the Alaskan Beaufort Sea Shelf” led by R. Pickart and including Stafford and Moore as PIs and “A Comprehensive

Modeling Approach Towards Understanding and Prediction of the Alaskan Coastal System Response to Changes in an Ice-diminished Arctic" led by W. Maslowski with J. Cassano and J.J. Walsh as co-PIs. The former project focuses on physical oceanography, upwelling, and bowhead whale distribution in a region further to the east of Barrow using a combination of year-long oceanographic and whale acoustic recorder moorings and field observations. Not only does the work of the Pickart NOPP project together with this project extend the spatial range of observations, field logistics were conducted in collaboration. For example, the Healy cruises that deployed moorings for this project also deployed the moorings for the Pickart NOPP in a very fruitful collaboration between the two projects. Several CTD casts were conducted near the Pickart NOPP moorings during the transit of the 2008 *R/V Annika Marie* from Barrow to Prudhoe Bay. The latter project applies state-of-the-art regional modeling of sea ice, ocean, atmosphere and ecosystem to provide a system approach to advance the knowledge and predictive capability of the diverse impacts of changing sea ice cover on the bio-physical marine environment of coastal Alaska. Hydrography acquired during surveys conducted from the *R/V Annika* Marie has been forwarded to Maslowski for comparison with model output.

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Lowry, LF, Sheffield G, George JC. 2004. Bowhead whale feeding in the Alaskan Beaufort Sea, based on stomach contents analyses. J. Cet. Res. Man. 6(3): 215–223.

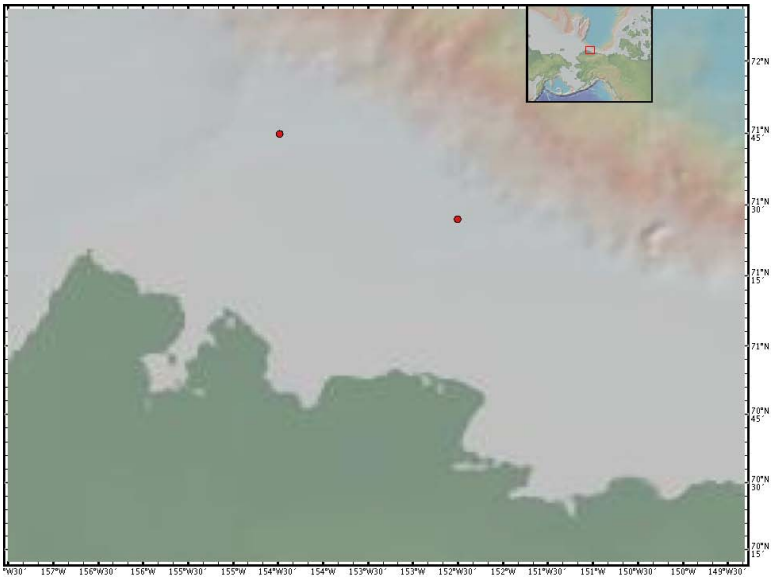

Figure 1. Locations (red circles) of moorings along the Beaufort Shelf break recovered during the 2010 Healy cruise.

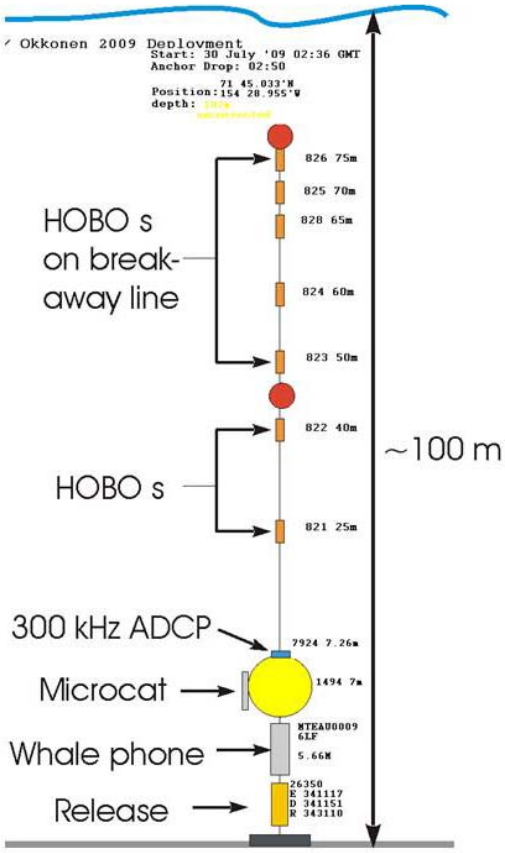

Figure 2. Schematic of the eastern mooring deployed at ~71.46°N, 152.50°W in 102 m of water. The western mooring differs only in that it does not have an ADCP . The HOBOs are thermistors that record water temperature.

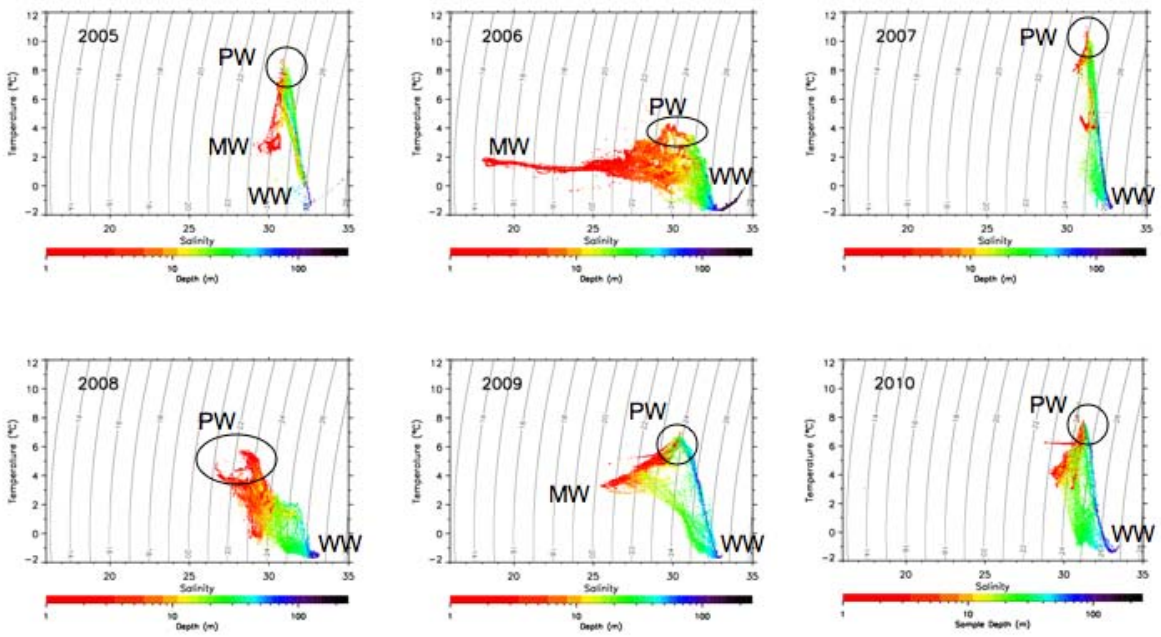

Figure 3. Temperature-Salinity plots of each year's aggregate (towed and individual cast) CTD data. Representative water masses are Pacific Water (PW), Winter Water (WW), and Meltwater (MW). Curved lines are isopycnals (constant sigma-t). Color indicates water depth at each data location.

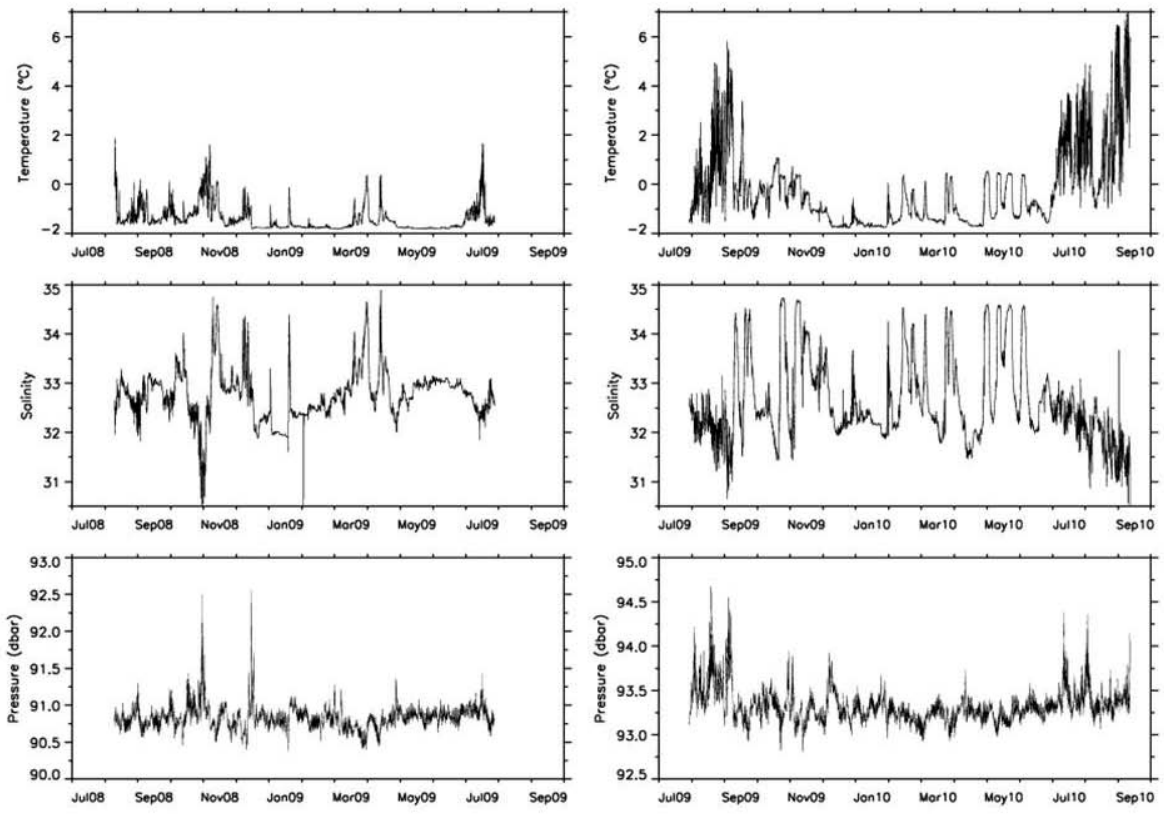

Figure 4. Time series of microcat-measured data from 2008/2009 (left) and 2009/2010 (right) deployments at the eastern mooring site. (top) temperature, (middle) salinity, and (bottom) pressure.

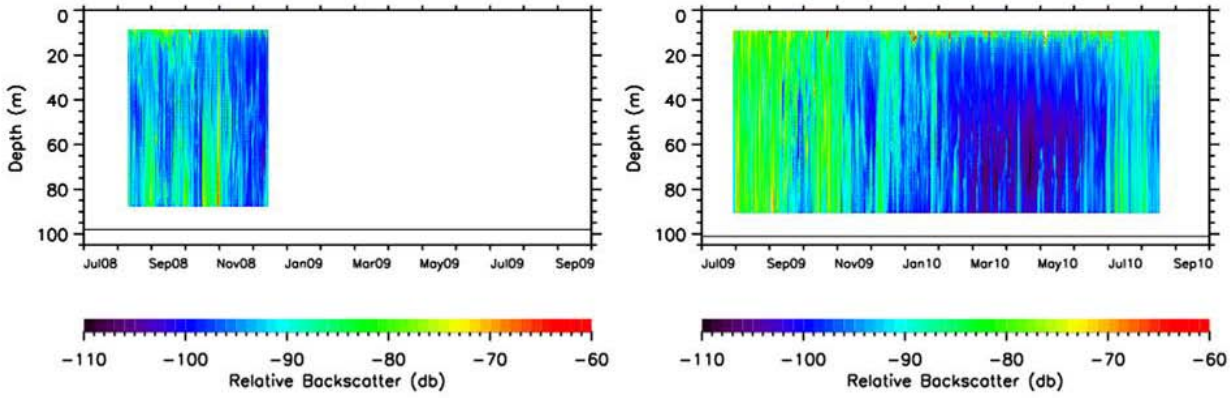

Figure 5. Time series of ADCP-measured relative acoustic backscatter from 2008/2009 (left) and 2009/2010 (right) deployments at the eastern mooring. The horizontal line indicates the bottom depth.

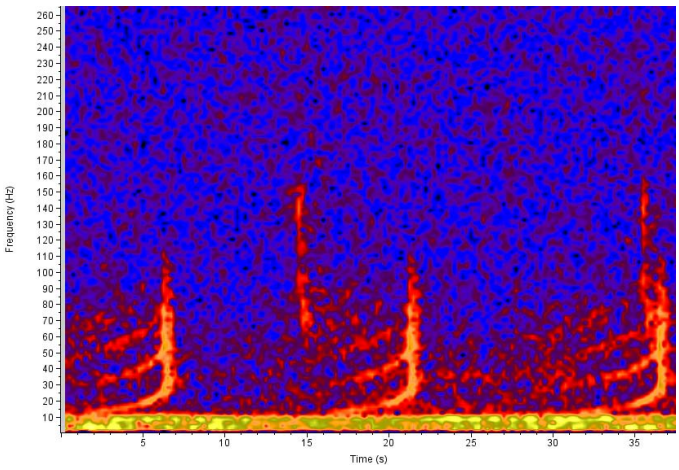

Figure 6. Sonogram of airgun shots recorded near Barrow, AK.

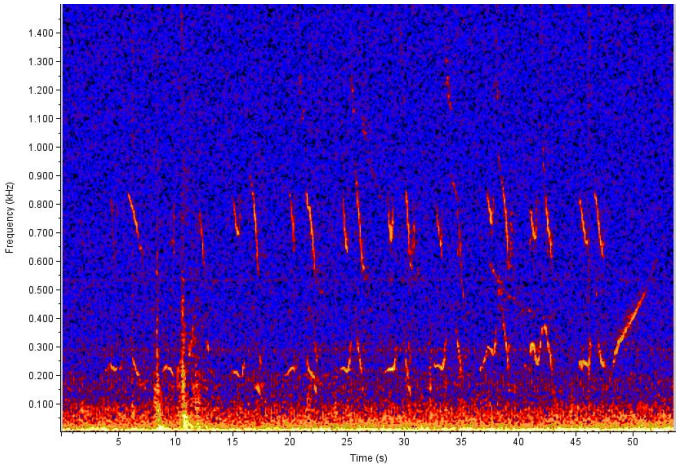

Figure 7. Sonogram of a bowhead whale "song".